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STUDY AND IMPROVEMENT OF THE S-1 PHOTOEMISSIVE SURFACE.(U)
JAN 68 H TIMAN DA-44-009-AMC-1811(E)

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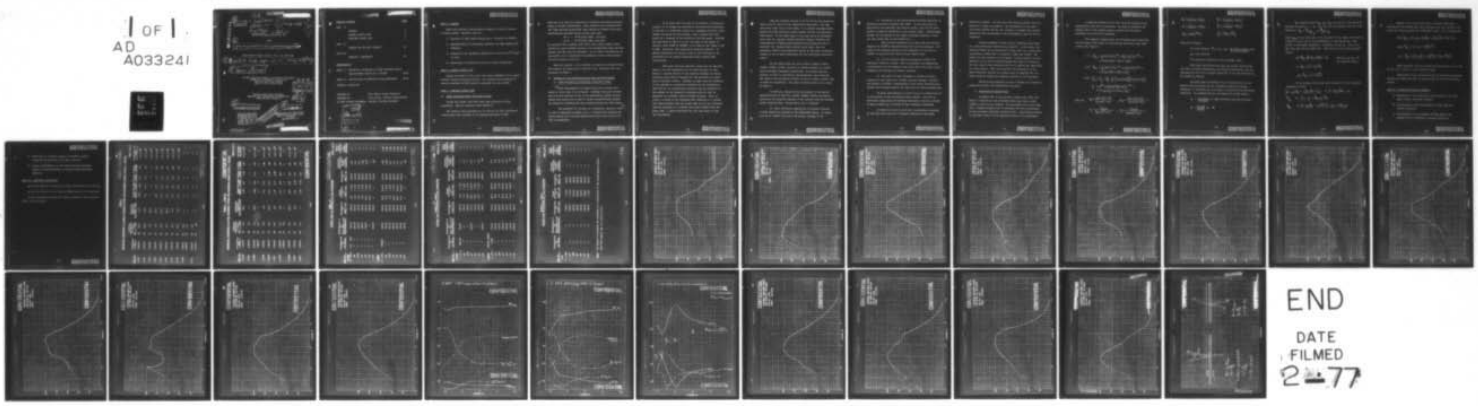

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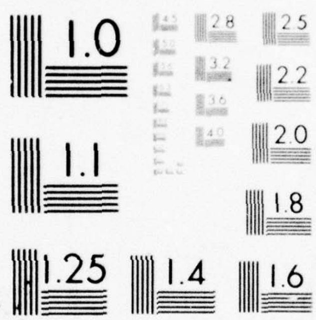

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(10) Hans Timan

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UNITED STATES ARMY ENGINEER
RESEARCH AND DEVELOPMENT LABORATORIES
FORT BELVOIR, VIRGINIA

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RELEASED BY: Alan Howell, Contract Administrator

DU MONT CONTROL DOCUMENTS: SI-6384, T6-2018, MO-10198

PART I - PURPOSE

Under this contract, photoelectric emission of the S-1 surface is being studied. Specific aims are:

1. Increase of white light sensitivity to 100 $\mu a/l$ for 2870°K.

2. Reproducibility of processing schedules for high sensitivity cathodes.

3. Lowering of the thermionic emission to a value of 10^{-13} A/cm^2 or less.

4. Measurement of physical and optical surface properties.

PART I - GENERAL FACTUAL DATA

During the month of July, nine tubes were assembled, all of which attained cathode processing status. Two surfaces were processed in vessels assembled by ERDL technical personnel for use at ERDL.

PART I - DETAILED FACTUAL DATA

A) Tubes processed during the month of July

During this month, four more tubes were processed on TiO_2 substrates. They are reported under Section B.

Two surfaces were processed for Ft. Belvoir in 7052 cylindrical vessels which were supplied by the Engineering Staff of ERDL.

They are to be used for comparison of absolute sensitivity measurements of several laboratories. Both surfaces were processed with the "high infrared processing" (hip) method and behaved very well. Sensitivities measured several months later gave

on I - WL 60 μA/L; 2540, 6.1 μA/L

on II - WL 70 μA/L; 2540, 11.4 μA/L

We processed four surfaces with "hip"; Nos. 0-251, 0-255, 0-259, resulted in good cathodes; however, the spectacularly high infrared figures from May were not equalled. In No. 0-257, K-prewetting was successful, but no thermionic measurements could be taken because the tube cracked on tip off.

Spectral response of the surfaces of interest processed during this quarter are given here as Figures 1-12. Technical data are contained in Table I.

B) Summary of work performed during this quarterly period

1. Tubes processed on dielectric substrates (TiO_2)

This investigation was begun during this quarter and a number of tubes have been processed. Although very good cathodes have not been achieved in any of the experiments, medium sensitivities were common and no sign of severe incompatibility between the dielectric substrate and the cathode material has been found.

The formation of cathodes on a dielectric substrate which in turn is deposited on glass, (i.e., a transmissive cathode) was chosen because of a two-fold application which could result from this investigation.

It is known that the only way to improve a transmissive cathode, or to change its performance characteristics optically, is the use of a dielectric spacer of a coupling refractive index between the glass and the cathode. Such a spacer will then result in a lowering of the reflection into the glass. Although the reflection in the S-1 is not very high in the region of interest (from 7000Å to 11000Å), it is still in the range of 12% to 25%. Therefore, some improvement could be expected. Of greater importance, of course, would be such lowering of the reflection for the alkali antimonides which display high reflectivity.

The second and more important reason for our approach, however, was the assumption that we could develop, in this manner, a clearer picture of the necessary changes in cathode formation which will be required for the formation of a good space reflective cathode. Thereby, we infer that the formation of the cathode on a dielectric substrate in the transmissive mode will not be considerably different from the formation of the cathode on the dielectric substrate which in turn is deposited on a metallic mirror instead of glass. This, of course, is based on the reasoning that formation of a cathode with light incident from the vacuum side is not very different from the formation of a cathode with light incident from the glass side. A later experiment has cast some doubt on this last assumption.

TiO_2 was selected because it is one of the few substances which could be used for both applications described. Its high refractive index (2.5 to 2.6) makes it a suitable coupling medium between the high refractive index cathode and the 1.5 refractive index glass. On the other hand, it has been shown in investigations (See for instance Interim Technical Report, "Studies and Investigation of Enhanced Photoemission from Reflective Photocathodes" (U), October 1966, Aerojet Delft Corp.) that the refractive index of the dielectric spacer in the space reflective cathode is not of great importance for its performance characteristics.

Of the tubes processed, Nos. 0-240T, 0-244T, 0-249T, 0-252T, 0-254T, 0-276T, resulted in medium cathodes; No. 0-253T never developed reasonable sensitivity. On several surfaces, optical, as well as electrical, characteristics were measured. The optical data are given in Table II where a normal surface 113A is added for comparison. The usual electrical data can be found in Table I.

In addition, Figures 13-15 show graphs of the optical characteristics of Tubes No. 0-240T, 0-244T, 0-276T and Figures 16-19 give the spectral response of the surfaces with the somewhat better sensitivities. Several facts are of interest:

1) Front reflection suppression is actually observed. A clear minimum is observed in the 4500-5000Å region. An exception is No. 0-252T with only a 5% initial coverage of Ti.

2) Absorption in the photocathode-plus-TiO_2 substrate is generally increased (compare with 113A). As the TiO_2 layer is practically non-absorbing (See Figures 13-15), this can be interpreted as enhanced absorption in the cathode layer. Interestingly enough, the absorption in the longer wavelength appears to drop off more slowly than in the normal S-1.

This is also reflected in the fact that the absolute response at 11500Å is relatively high for such low surfaces. The slope of the spectral response (with exception of the thin No. 0-252T) is also more flat than in most normal cases.

3) On all surfaces (again excepting No. 0-252T) the thermionic emission is high. This is optically not explainable. A contribution due to centers in the thick TiO_2--(Cs) layer cannot completely be excluded, is however unlikely.

4) The ratio of Front Incidence to Vacuum Incidence response is very high in No. 0-244T, and goes through a maximum and minimum in 0-276T. Measurements of the vacuum reflection may explain this unusual behavior but they have not been performed yet.

Of these observations, 1) and 2) can be of importance for an improvement of the transmissive type cathode. The fact of reflection suppression and increased absorption could be utilized if good cathodes can be formed on this dielectric substrate.

It should be borne in mind that, eventually, processing on the TiO_2 layer will be of interest primarily in the space

reflective cathode. In this case, the vacuum incidence response should be as high as possible. The performance of the space reflective cathode (Sp RC) can, however, be judged only approximately from the performance of the transmissive type for vacuum incidence.

Several attempts to form a good, continuous TiO_2 layer on a metal reflector have been unsuccessful. In all cases, the titanium "broke up" in conversion to TiO_2; that is, a discretely crystalline, rather than a continuous, layer was formed. The reason for this behavior is not known. It may, however, be that exposure to air and the sealing flames have much to do with it. Our next step in this direction will be to perform all operations in a good vacuum. That also includes the preparation of the metal reflector, because in several cases it appeared that the metal reflector itself was severely attacked in the TiO_2 bake.

One Sp RC was processed on such a "broken up" substrate; processing behavior and sensitivity were poor.

2. Correction of Optical Data

In Report #36, of the previous effort, pgs. 10-12 and Figure 9 formulas had been developed which were used to hand compute n and k on one surface. It was pointed out at that time that a computer program will be desirable and that a correction for the air-glass interface should be made. Interference effects in the glass itself can be neglected because of its thickness.

A computer program has now been received through private communication and will be evaluated. In order to establish the optical data of the cathode proper, formulas for the above-mentioned correction have developed.

The computer program gives the following three quantities for the single film, which are essentially equivalent with those of Rpt. #36, Figure 9.

$$\text{(I)} \quad R_{Fc} = \frac{1}{Z}\left(a_1^2+b_1^2\right)e^{2\alpha_1} + \left(a_2^2+b_2^2\right)e^{-2\alpha_1} + \\ + A\cos(2\delta_1) + B\sin(2\delta_1)$$

$$\text{(II)} \quad R_{Vc} = \frac{1}{Z}\left(a_1^2+b_1^2\right)e^{-2\alpha_1} + \left(a_2^2+b_2^2\right)e^{2\alpha_1} + \\ + A\cos(2\delta_1) + B\sin(2\delta_1)$$

$$\text{(III)} \quad T_{Fc} = T_{Vc} = \frac{n_2}{n_0}\,\frac{1}{Z}\left[(1+a_1)^2+b_1^2\right]\left[(1+a_2)^2+b_2^2\right]$$

$$Z = e^{2\alpha_1} + \left(a_1^2+b_1^2\right)\left(a_2^2+b^2\right)e^{-2\alpha_1} + \\ + C\cos(2\delta_1) + D\sin(2\delta_1)$$

Here are $$a_1 = \frac{n_0^2-n_1^2-k_1^2}{(n_0+n_1)^2+k_1^2} \quad ; \quad a_2 = \frac{n_1^2-n_2^2+k_1^2}{(n_1+n_2)^2+k_1^2}$$

$$b_1 = \frac{2n_0k_1}{(n_0+n_1)^2+k_1^2} \quad ; \quad b_2 = \frac{-2n_2k_1}{(n_1+n_2)^2+k_1^2}$$

$$A = 2(a_1a_2 + b_1b_2) \quad ; \quad B = 2(a_1b_2 - a_2b_1)$$

$$C = 2(a_1a_2 - b_1b_2) \quad ; \quad D = 2(a_1b_2 - a_2b_1)$$

$$\alpha_1 = 2\pi k_1 d_1/\lambda \quad . \quad \delta_1 = 2\pi n_1 d_1/\lambda$$

Refractive Indices:

$n_0 = 1.5$ (Glass); $\mathcal{N}_1 = n_1 - ik_1$ (absorbing medium, here the photocathode)

$n_2 = 1.0$ (Vacuum)

d_1 = physical thickness of the absorbing layer.

With these definitions R_{FC}, R_{VC}, T_{FC} become respectively the Front or Glass reflectivity, the Vacuum reflectivity, and the Transmission in % of an incident light wave λ of unit intensity in the medium n_0 (Glass).

Actually these intensities are not measurable as we can measure only quantities in air, incident as well as emerging. Therefore, a correction has to be made to account for the air-glass interface. For exemplification, see Figure 20 of this report.

r_G : Percentage of light reflected from the air-glass interface

$$r_G = \left[\frac{n_0 - n_1}{n_0 + n_1}\right]^2 \approx .04$$

The computer values R_{FC}, R_{VC}, T_{FC}, are the % of the amplitude entering the glass : $1 - r_G$. Our recorded and measured value of front reflection $R_F = \bar{R}_F / R_{FAg} = \bar{R}_F / 1-\varepsilon_\lambda$

where R_{FAg} is the reflection of an Ag mirror in the same constellation. (ε_λ is a factor due to the imperfections of the Ag mirror. This factor is wavelength dependent.) Similarly for R_V, T_F. (See, e.g., Rpt. #21, pgs 7-8 and Figure 24). This gives in first order approximation:

$$\text{(IV)} \quad R_{FC} = (1 + 2r_G - \varepsilon_\lambda) R_F - r_G$$

where R_F, R_V, T_F, are the measured values.

$$\text{(V)} \quad R_{VC} = (1 - \varepsilon_\lambda) R_V$$

$$\text{(VI)} \quad T_{FC} = (1 - r_G) T_F$$

If we consider the second order reflection on the air-glass interface we have:

$$(1 - \varepsilon_\lambda) R_F - r_G R_F (R_F - 2r_G) = (1 - 2r_G) R_{FC} + r_G$$

$$T_{FC} = (1 - r_G - R_{FC} r_G) T_F$$

$$R_{VC} = (1 - \varepsilon_\lambda) R_V - r_G T_F^2 (1 - 2r_G - 2R_V r_G)$$

Because of the very small terms of mostly third order involved, we can replace R_{FC}, R_{VC}, and T_{FC} by R_F, R_V, and T_F in the second and third equation for simplicity's sake. So we finally get:

$$\text{(VII)} \quad R_{FC} = (1 + 2r_G - \varepsilon_\lambda) R_F - r_G R_F (R_F - 2r_G) - r_G$$

$$\text{(VIII)} \quad T_{FC} = (1 - r_G - r_G R_F) T_F$$

$$\text{(IX)} \quad R_{VC} = (1 - \varepsilon_\lambda) R_V - r_G T_F^2 (1 - 2r_G - 2R_V r_G)$$

These equations will now supply the values which can be used in (I), (II), (III) for the computer program.

Computation of the corrected values for previously measured surfaces has begun and will be reported upon in the next quarterly report.

PART II - PROGRAM FOR THE NEXT INTERVAL

1) Preparation of the combination metal reflector and TiO_2 layer without "break-up" effects.

2) Continuation of the investigation of TiO_2 substrate cathode formation.

3) Determination of the thickness of TiO_2 layers from optical data to facilitate thickness selection.

4) Evaluation of computer program to determine optical constants and thickness on several surfaces.

5) Further investigation of the high infrared processing method and doping attempts to suppress high thermionic emission.

PART III - MEETINGS, CONFERENCES

On May 26, 1967 Dr. H. Timan of Du Mont visited ERDL, Ft. Belvoir.

On June 23, 1967 Dr. H. A. Stahl of ERDL visited the Du Mont Lab.

On both occasions, progress and future activity of this research effort were discussed.

TABLE I

ELECTRICAL PROPERTIES OF TUBES PROCESSED DURING THE QUARTERLY PERIOD 5/1/67 - 7/21/67

Tube No.	Processing Date	Luminous Sensitivity in μA/L WL	Luminous Sensitivity in μA/L 2540	Thermionic Emission in A/cm² 10^{12}	Absolute Sensitivity in mA/W 4535Å	6015Å	9500Å	11500Å	Resistance in Ω/□
0-209	5/02/67	66	11.5	5.2	2.85	3.35	2.3	.19	3.3×10^6
0-211	5/03/67	68	10.0	62.0	3.9	5.3	1.8	.14	5.0×10^5
0-213	5/05/67	52	8.8	12.0	--	--	--	--	1.0×10^6
0-215	5/11/67	51	7.5	11.0	3.0	3.8	1.6	.35	6.0×10^7
0-216	5/08/67	46	5.2	47.0	2.6	4.0	1.9	.18	1.2×10^9
0-218	5/09/67	45	5.7	40.0	2.7	3.5	1.3	.17	7.5×10^6
0-220	5/16/67	34	4.6	0.6	2.7	3.2	1.5	.08	2.0×10^8
0-221	5/18/67	68	12.5	5.5	2.2	3.0	2.4	.42	2.0×10^4
0-232A	6/01/67	55	6.5	--	--	--	--	--	--
	6/08/67	25	1.9	--	--	--	--	--	--
0-233	6/01/67	51	5.5	--	--	--	--	--	--
	6/07/67	28	.60	--	--	--	--	--	--

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TABLE 1 (CONT'D)

ELECTRICAL PROPERTIES OF TUBES PROCESSED DURING THE QUARTERLY PERIOD 5/1/67 - 7/21/67

Tube No.	Processing Date	Luminous Sensitivity in µA/L WL	Luminous Sensitivity in µA/L 2540	Thermionic Emission in $A/cm^2 \times 10^{12}$	Absolute Sensitivity in mA/W 4535Å	Absolute Sensitivity in mA/W 6015Å	Absolute Sensitivity in mA/W 9500Å	Absolute Sensitivity in mA/W 11500Å	Resistance in Ω/□
0-234A	6/16/67	61	9.2	14.0	1.25	2.2	1.35	.05	8.0×10^3
0-236	6/21/67	65	7.0	--	--	--	--	--	--
0-244T	6/26/67	30	3.4 Best of TiO_2 tubes so far.	14.0	1.95	3.0	1.1	.03	3.0×10^5
	9/04/67	37	4.0	--	--	--		--	--
0-240T	6/21/67	27	1.4	1.0	2.6	2.5	--	.04	4.0×10^6
0-249T	7/03/67	27	4.3	92.0	2.0	2.6	1.05	.08	3.9×10^5
0-251	7/11/67	50	6.2	4.2	1.8	3.0	1.85	.07	1.5×10^{10}
0-252T	7/08/67	37	3.9	0.6	2.1	3.0	1.4	.01	6.0×10^5
	9/01/67	32	1.9	--	--	--	--	--	--
0-254T	7/20/67	37	2.5	15.0	4.8	5.9	1.0	.03	2.3×10^7
0-255	7/21/67	55	6.8	6.6	3.2	4.75	2.0	.18	5.0×10^7
0-259	7/20/67	68	6.2	--	4.35	6.25	2.3	.07	--

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TABLE II
OPTICAL DATA OF SURFACES ON TiO2 SUBSTRATES

Tube No.	Transmission of Ti Layer		Transmission T of TiO_2 Layer in % Reflection=1-T	Transmission of TiO_2 + Si	Front Reflection of TiO_2 + Si		Absorption of TiO_2 + Si	Absolute Sensitivity in mA/W Front Incidence	Ratio Front Incidence to Vacuum Incidence
0-240T									
λ = .39 μ	~75	(72)	(92.5)	(70.5)	6.5	(2.5)	(27.0)	2.8	--
.45	"	"	(91.5)	(67.0)	4.2	(0.5)	(33.0)	2.6	--
.505	"	"	(93.5)	(53.5)	6.0	(2.0)	(44.5)	2.5	--
.60	"	"	(94.0)	(39.5)	9.5	(6.0)	(54.5)	2.45	--
.80	"	"	(94.5)	(30.0)	12.5	(9.5)	(60.5)	1.75	--
.95	"	"	--	(30.0)	11.5	(8.5)	(61.5)	--	--
1.15	"	"	(96.0)	(30.0)	--	--	(61.0)	.05	--
0-244T									
λ = .39 μ	(38-40)		(63.5)	(61.5)	15.5	(12.0)	(27.0)	2.25	1.95
.45	"		(75.0)	(62.5)	8.5	(5.0)	(33.0)	1.95	1.50
.505	"		(83.0)	(48.0)	7.0	(3.0)	(49.0)	2.5	1.75
.60	"		(85.0)	(35.0)	10.5	(7.0)	(58.0)	3.0	1.75
.80	"		(89.0)	(24.5)	16.5	(14.0)	(62.0)	2.6	1.65
.95	"		(91.0)	(24.5)	17.0	(14.0)	(61.5)	1.1	1.60
1.15	"		(92.0)	(30.5)	--	--	--	.03	2.15 -

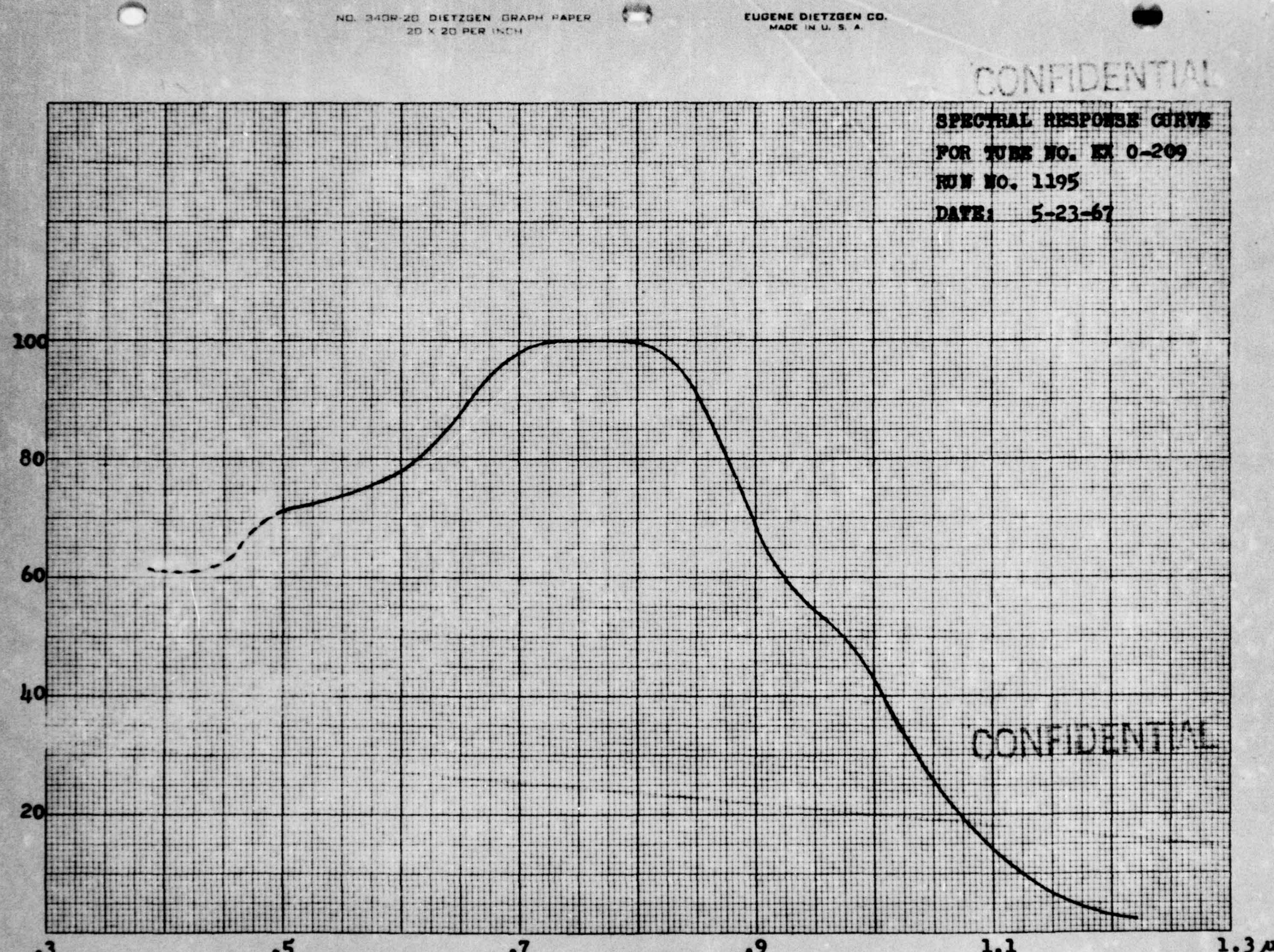
TABLE II - CONT'D
OPTICAL DATA OF SURFACES ON TiO_2 SUBSTRATES

Tube No.	Transmission of Ti Layer	Transmission T of TiO_2 Layer in % Reflection=1-T	Transmission of TiO_2 + Si	Front Reflection of TiO_2 + Si		Absorption of TiO_2 + Si	Absolute Sensitivity in mA/W Front Incidence	Ratio Front Incidence to Vacuum Incidence
0-252T								
= .39 µ	(86-90)	(94.0)	(82.0)	6.0	(2.0)	(16.0)	--	--
.45	"	--	(75.0)	7.5	(4.0)	(21.0)	2.1	--
.505	"	--	(56.5)	10.5	(7.0)	(36.5)	--	--
.60	"	(96.0)	(35.5)	14.0	(11.0)	(53.5)	3.0	--
.80	"	--	(31.5)	12.5	(9.5)	(59.0)	--	--
.95	"	--	(33.5)	11.5	(8.5)	(58.0)	1.4	--
1.15	"	(96.0)	(38.5)	--	--	~(54.0)	.01	--
0-276T	Nearly opaque							
= .39 µ	2-5%	(74.0)	(43.0)	24.0	(20.5)	(36.5)	2.1	.75 !
.45	"	(63.5)	(42.5)	23.0	(20.0)	(37.5)	1.5	1.30
.505	"	(77.5)	(42.0)	6.0	(2.5)	(55.5)	1.6	1.55
.60	"	(99.5) !	(29.5)	18.5	(15.5)	(55.0)	1.4	1.00
.80	"	(80.5)	(20.5)	22.0	(19.5)	(60.0)	1.4	1.30
.95	"	(76.5)	(21.0)	19.0	(16.5)	(62.5)	.70	1.50
1.15	"	~(68.0)	(24.0)	--	--	~(62.0)	.08	2.50 !

TABLE II - CONT'D
OPTICAL DATA OF SURFACES ON TiO_2 SUBSTRATES

Tube No.	Transmission of Ti Layer	Transmission T of TiO_2 Layer in % Reflection=1-T	Transmission of TiO_2 + Si	Front Reflection of TiO_2 + Si	Absorption of TiO_2 + Si	Absolute Sensitivity in mA/W Front Incidence	Ratio Front Incidence to Vacuum Incidence
113A							
λ = .39µ	--	--	(70.5)	(6.0)	(23.5)	--	--
.45	--	--	(60.5)	(9.0)	(30.5)	--	--
.505	--	--	(48.5)	(12.5)	(39.0)	--	--
.60	--	--	(34.0)	(15.5)	(50.5)	--	--
.80	--	--	(28.5)	(12.5)	(59.0)	--	--
.95	--	--	(32.5)	(10.5)	(57.0)	--	--
1.15	--	--	(39.0)	(8.5)	(53.5)	--	--

Note: All figures in brackets are corrected for contribution of the second glass surface. (See this report, pg. 11, (VII) to (IX).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EUGENE DIETZGEN CO.
MADE IN U. S. A.
SPECTRAL RESPONSE CURVE
FOR TUBE NO. EX 0-209
RUN NO. 1195
DATE: 5-23-67
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80
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1.1
1.3 μ

FIGURE 1

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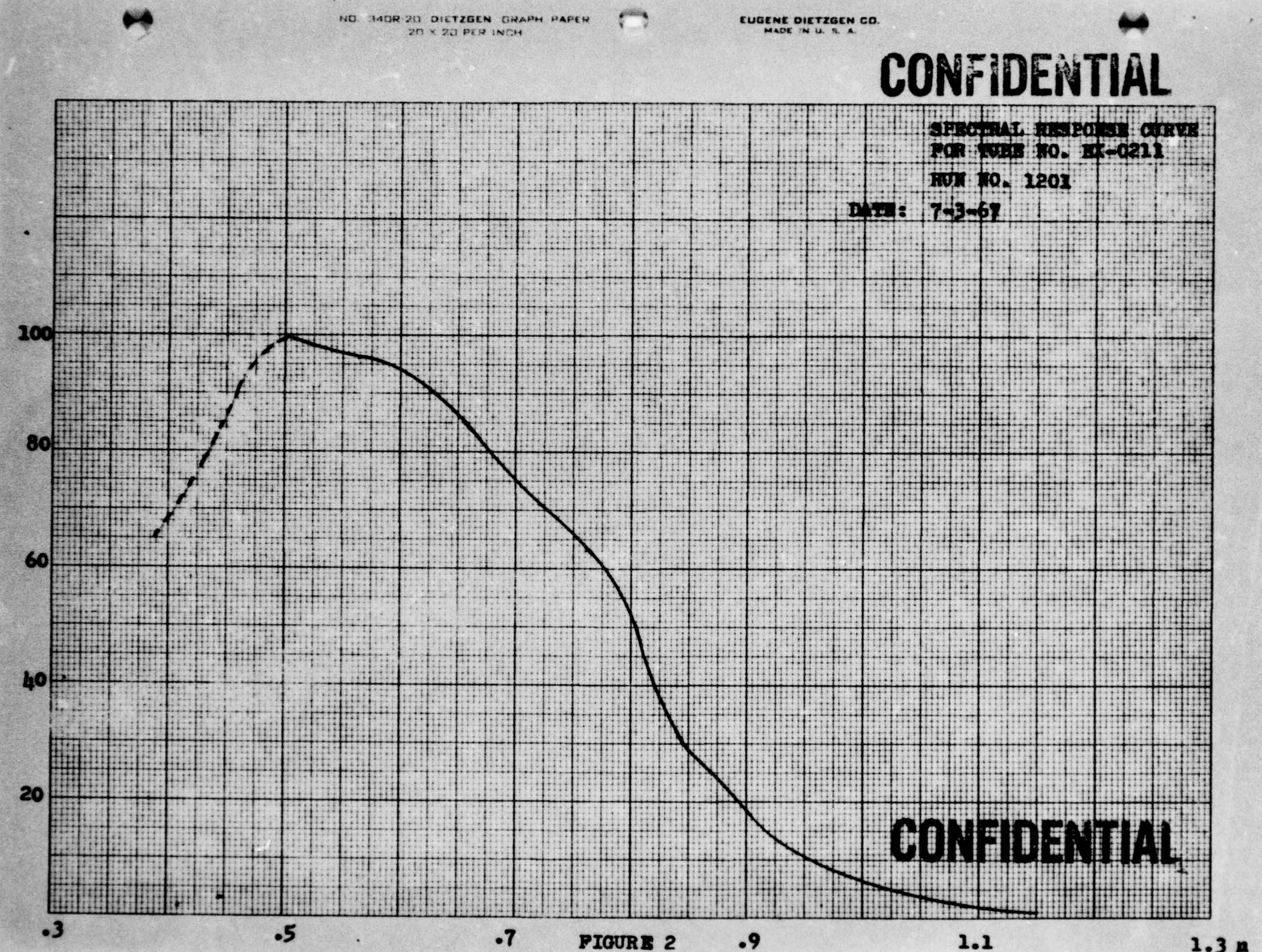

FIGURE 2

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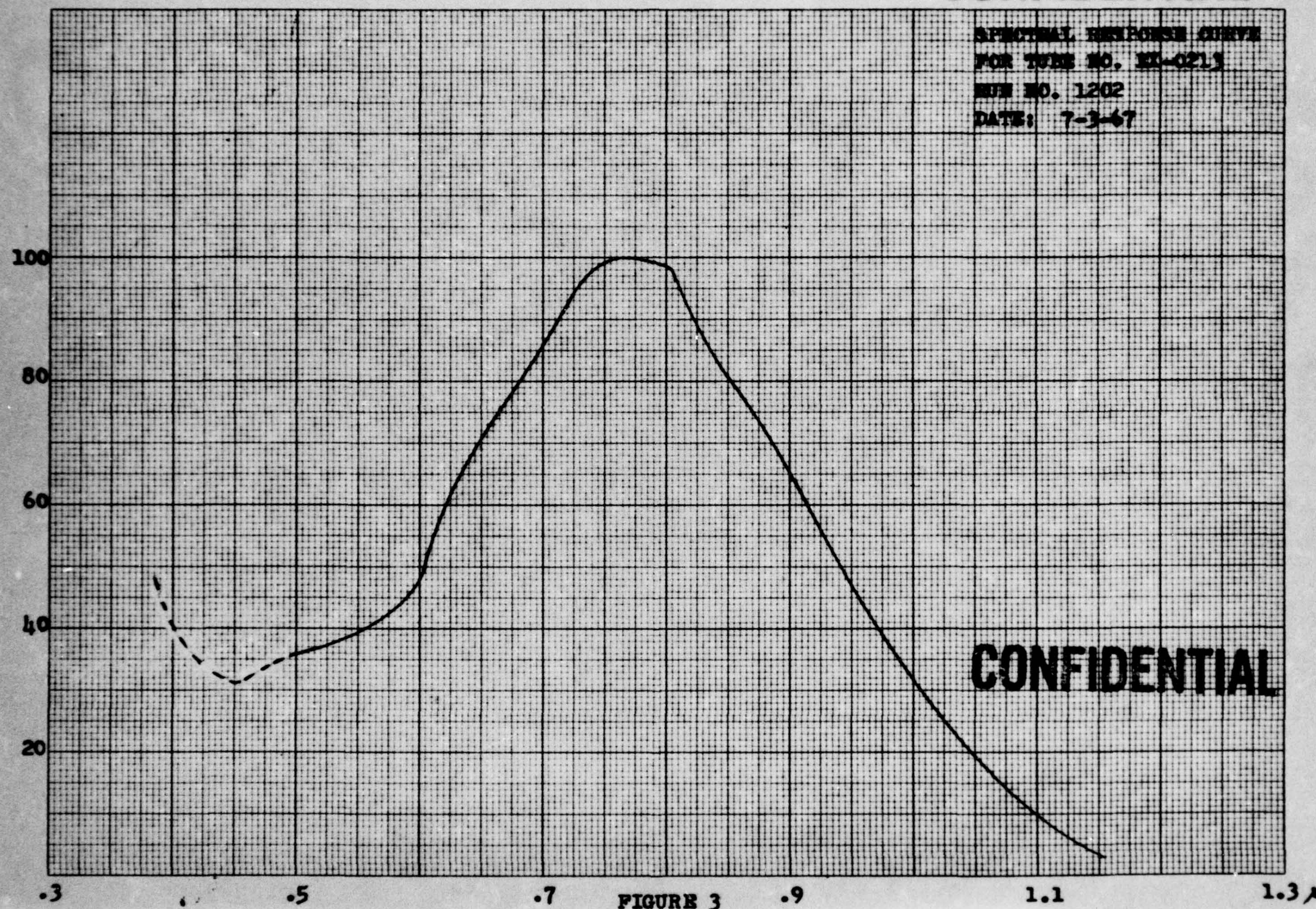
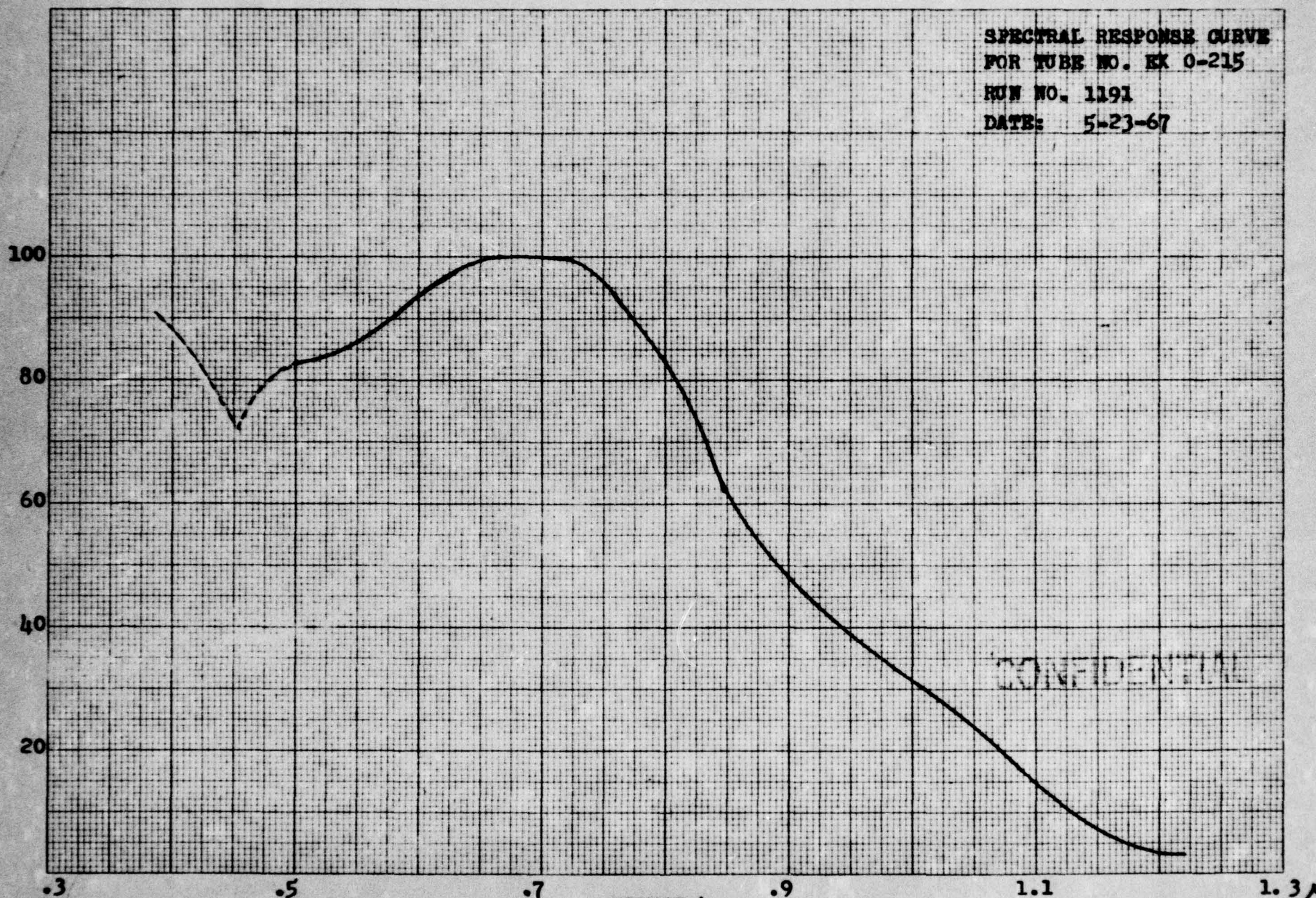


FIGURE 3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RUN NO. 1191
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1.3 μ
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FIGURE 4

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EUGENE DIETZGEN CO.
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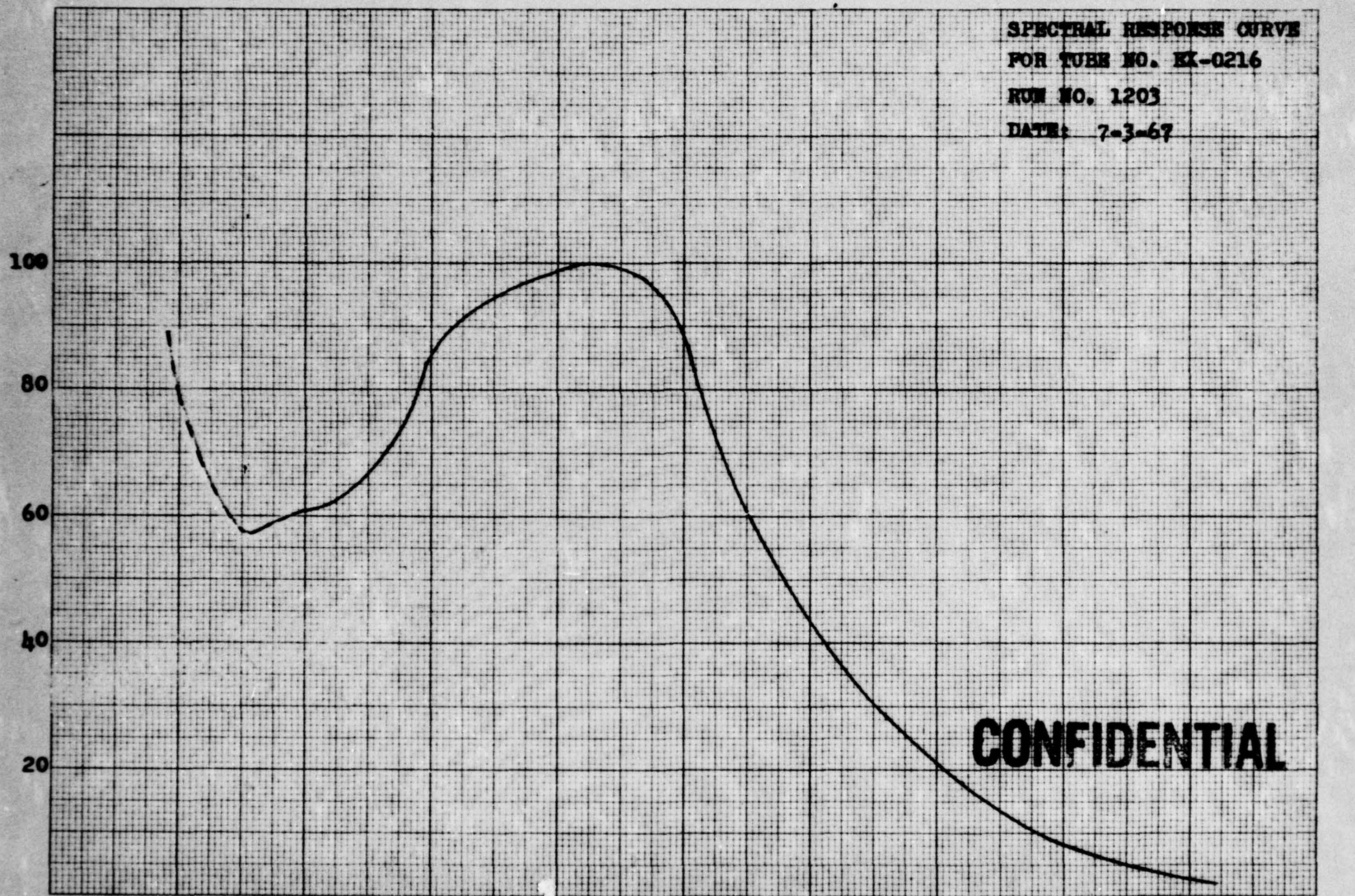


FIGURE 5

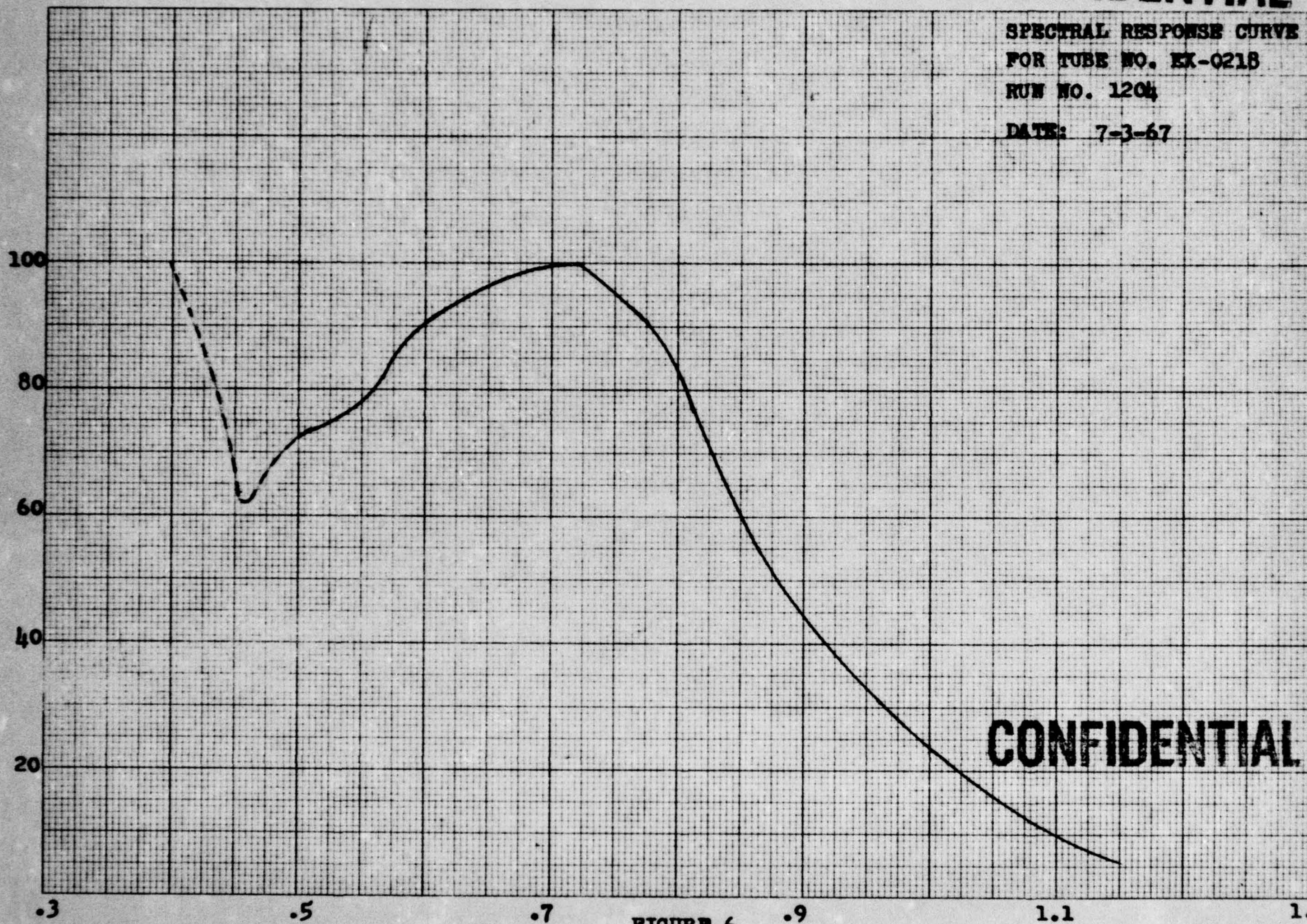

SPECTRAL RESPONSE CURVE
FOR TUBE NO. EX-0218
RUN NO. 1204
DATE: 7-3-67
100
80
60
40
20
.3
.5
.7
.9
1.1
1.3 μ

FIGURE 6

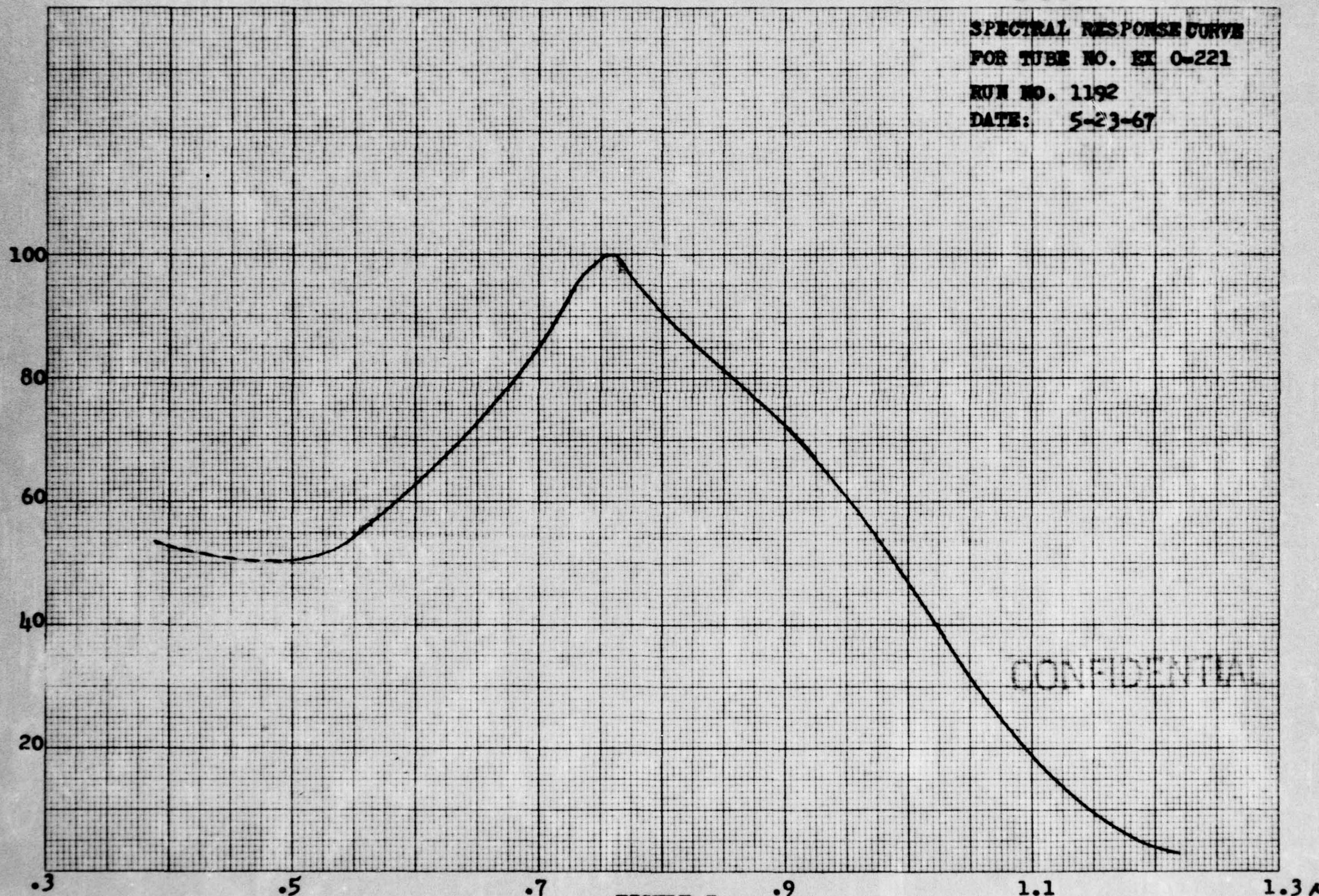

SPECTRAL RESPONSE CURVE
FOR TUBE NO. EX 0-221
RUN NO. 1192
DATE: 5-23-67
100
80
60
40
20
.3
.5
.7
.9
1.1
1.3 μ

FIGURE 7

NO. 340R-20 DIETZGEN GRAPH PAPER
20 X 20 PER INCH

EUGENE DIETZGEN CO.
MADE IN U. S. A.

CONFIDENTIAL

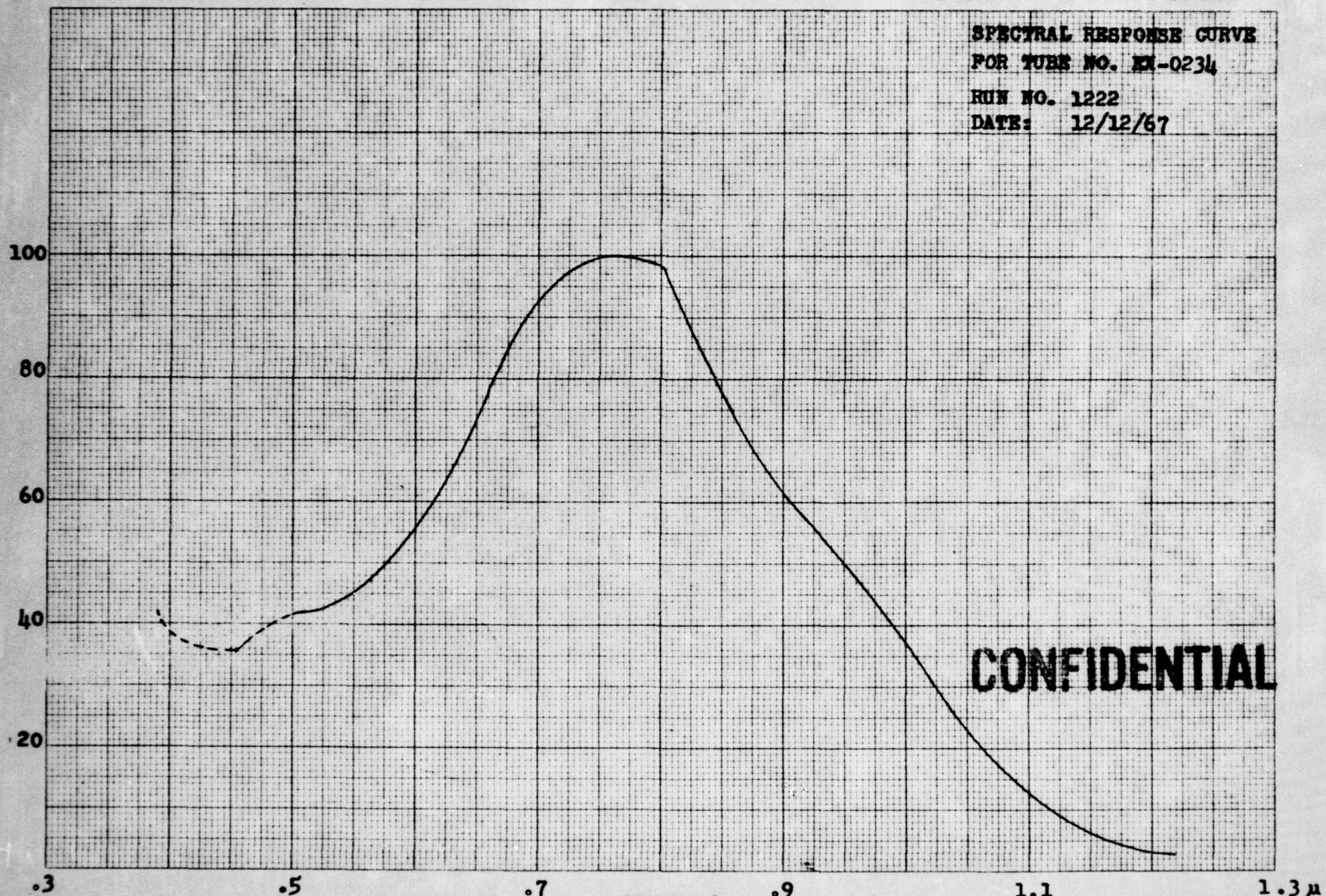
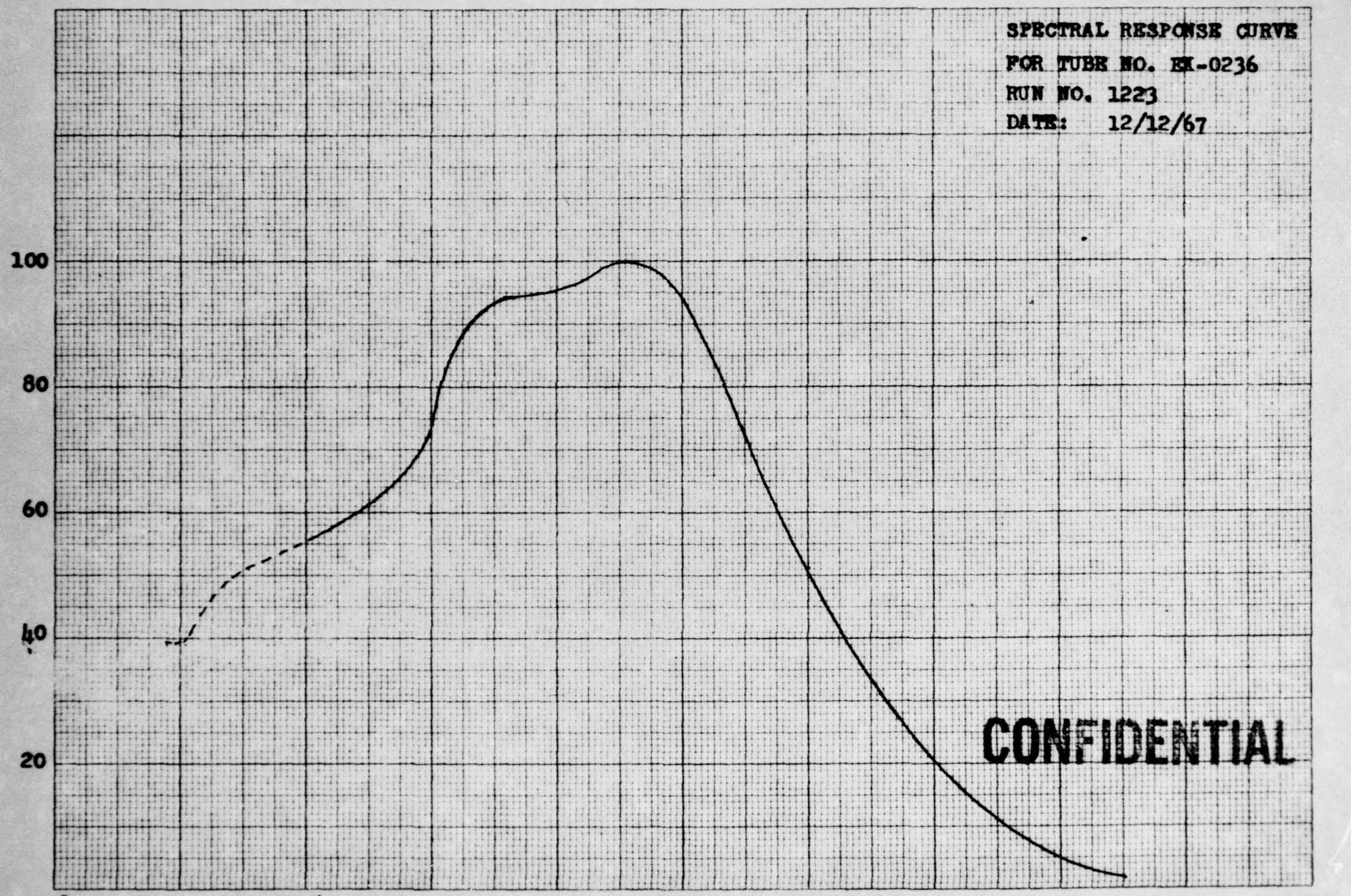


FIGURE 8



CONFIDENTIAL

FIGURE 9

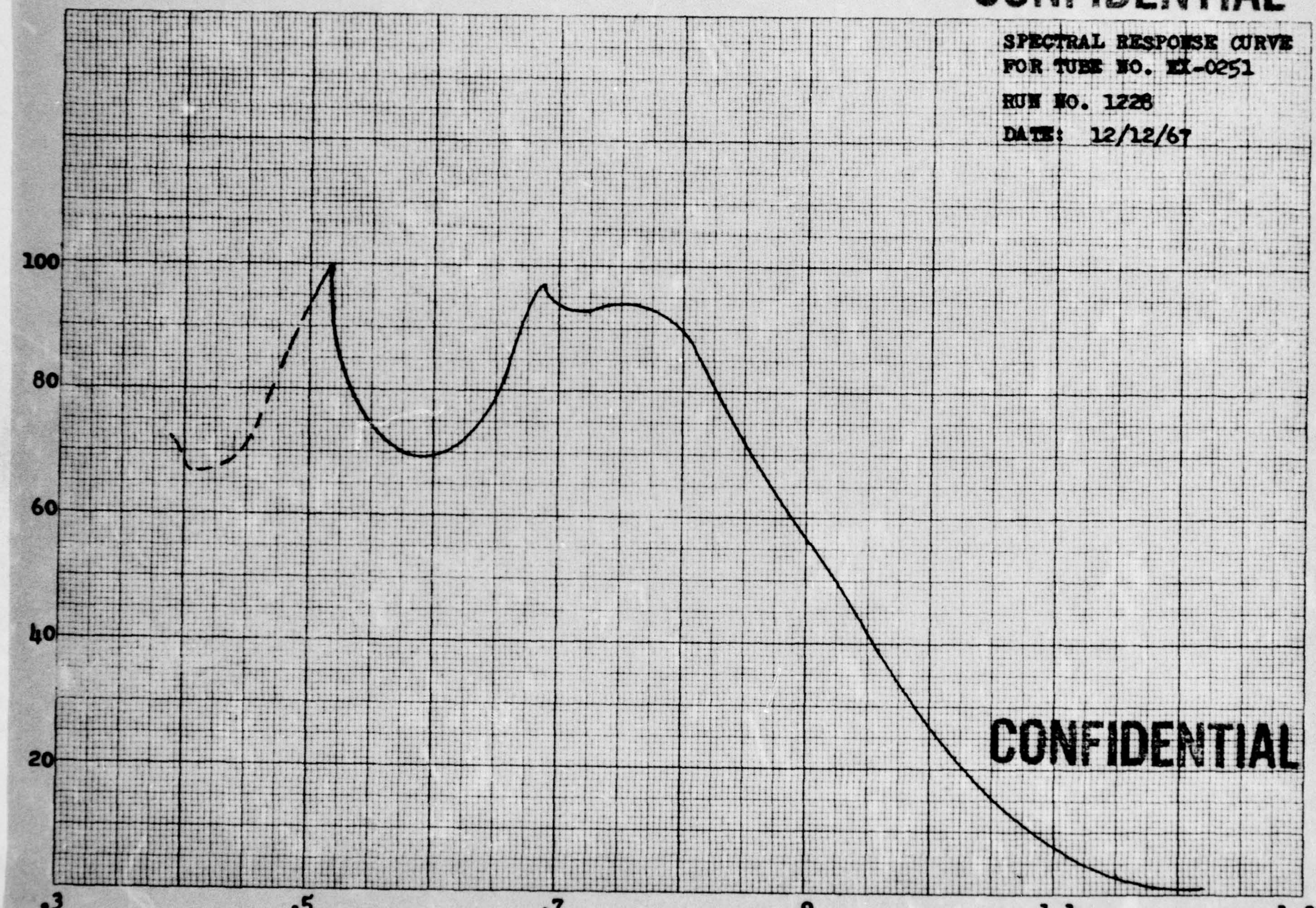

SPECTRAL RESPONSE CURVE
FOR TUBE NO. EX-0251
RUN NO. 1228
DATE: 12/12/67
100
80
60
40
20
.3
.5
.7
.9
1.1
1.3 μ

FIGURE 10

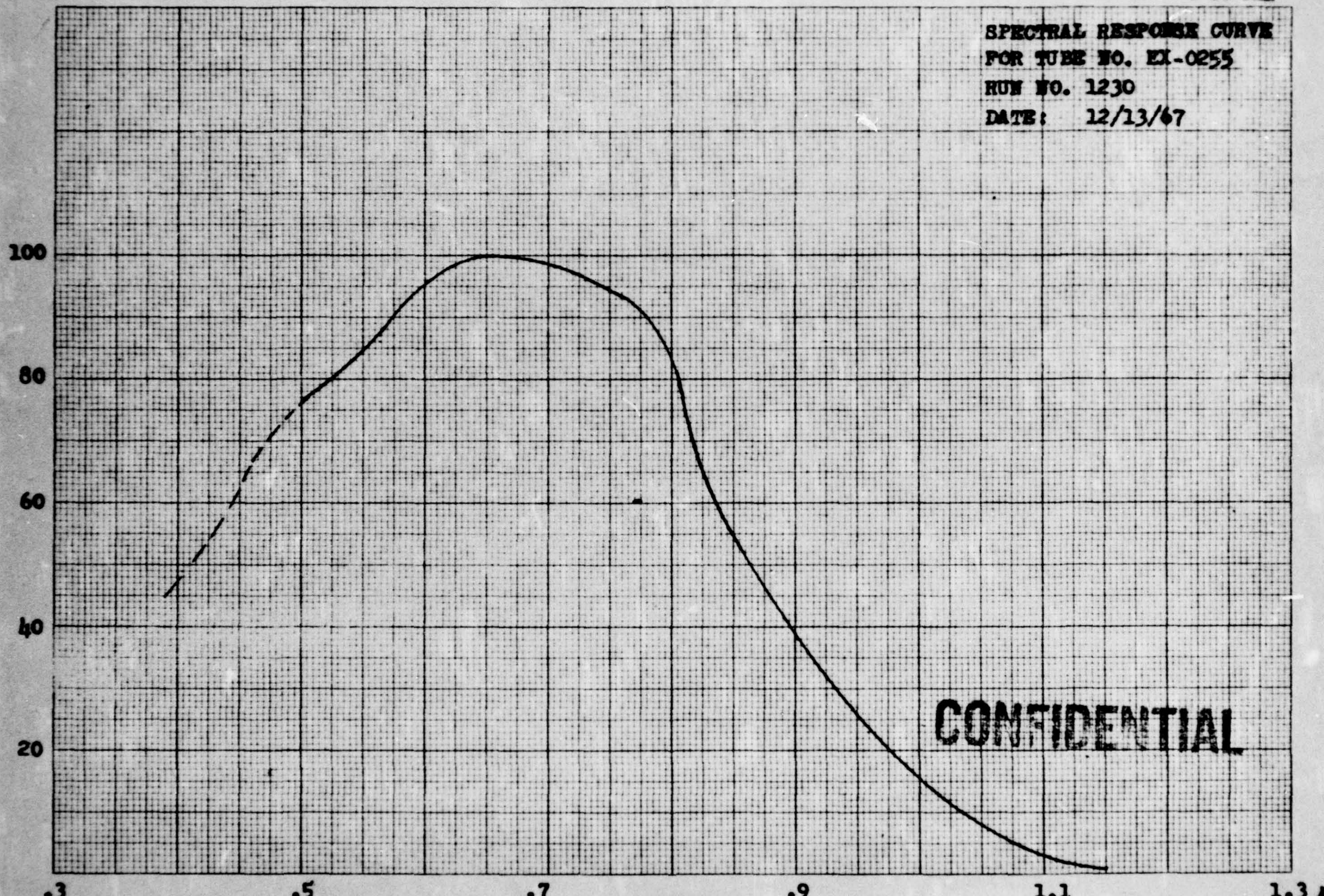

SPECTRAL RESPONSE CURVE
FOR TUBE NO. EX-0255
RUN NO. 1230
DATE: 12/13/67
100
80
60
40
20
.3
.5
.7
.9
1.1
1.3 μ

FIGURE 11

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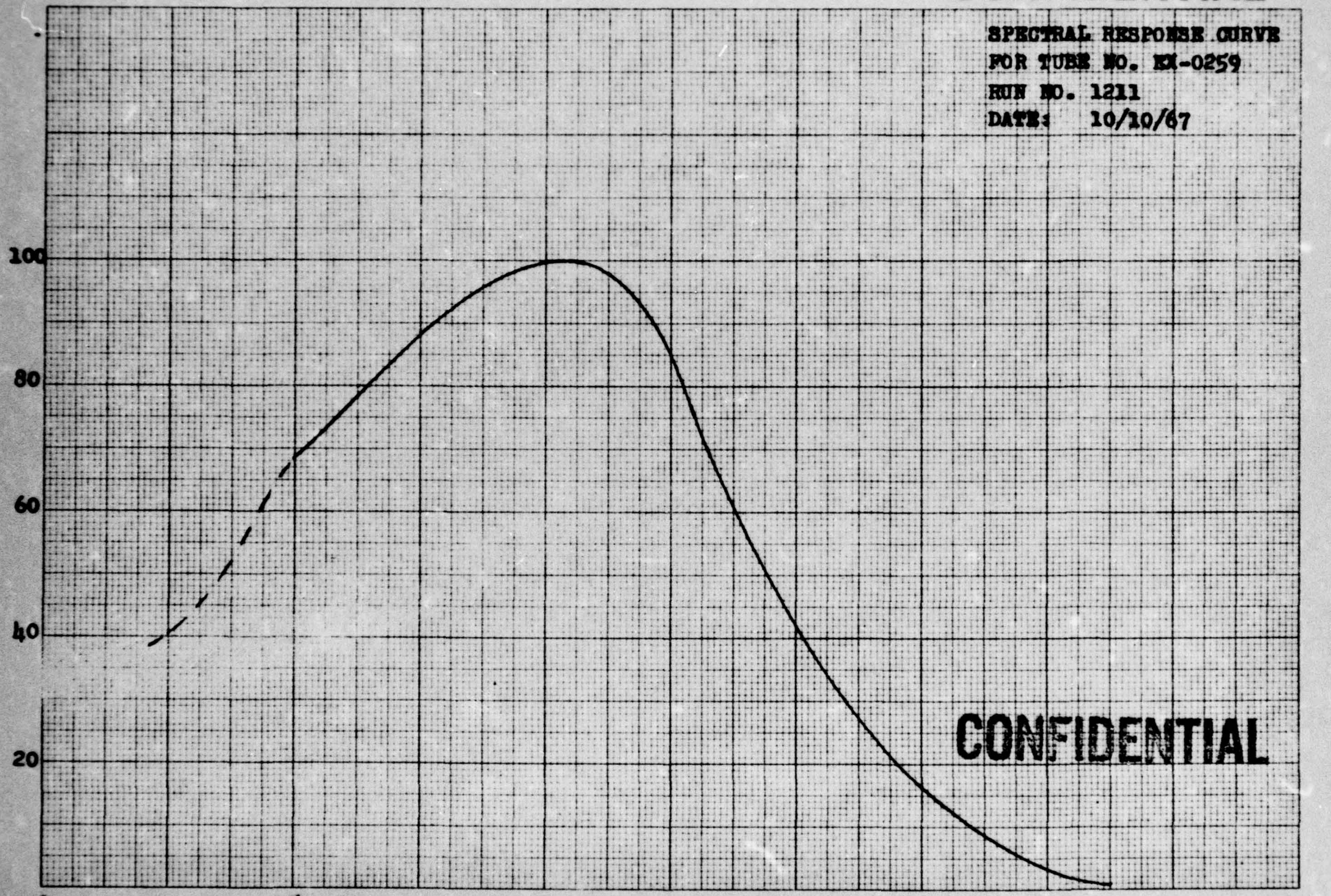

FIGURE 12

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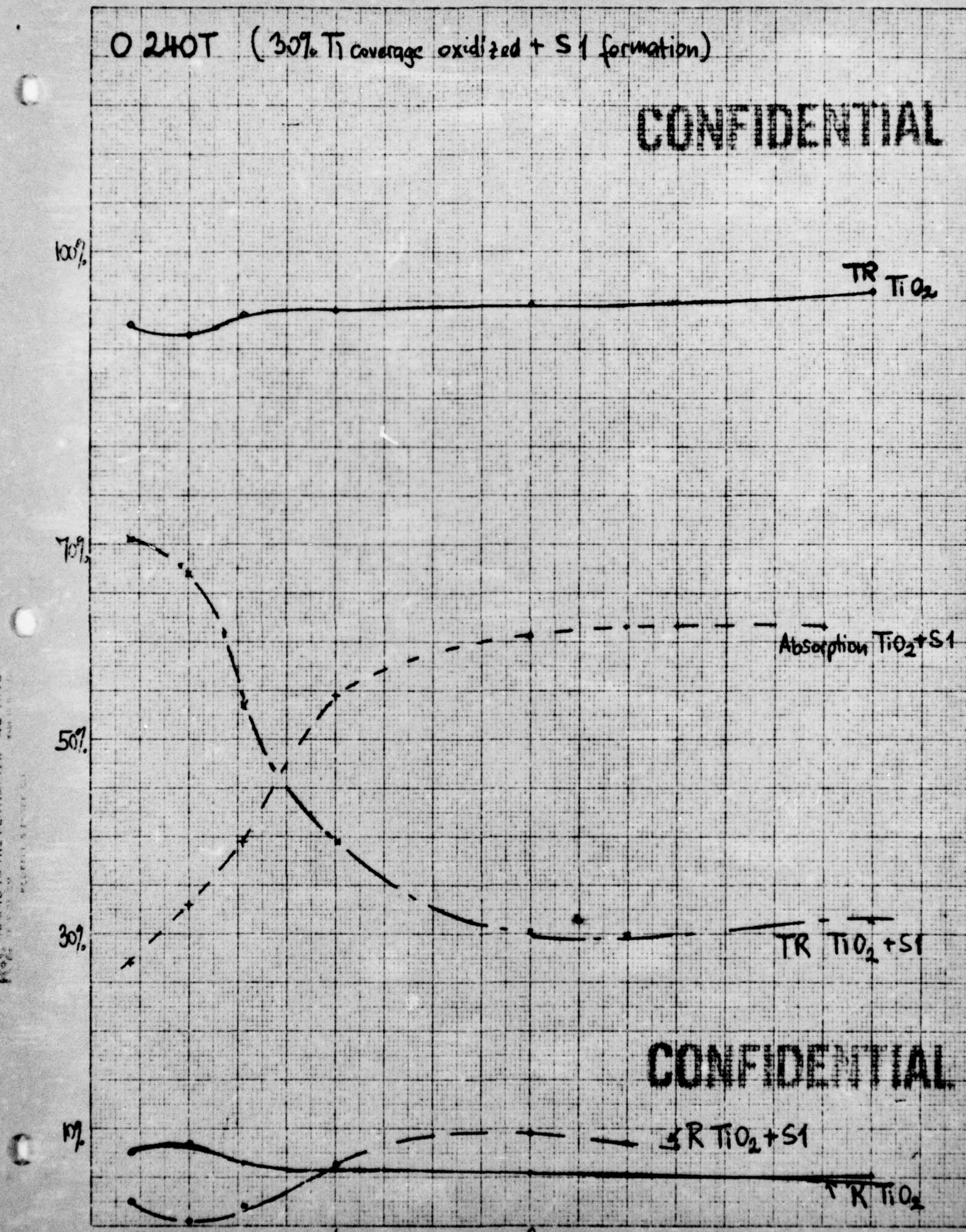

O 240T (30% Ti coverage oxidized + S1 formation)
100%
70%
50%
30%
10%
TR TiO_2
Absorption TiO_2+S1
TR TiO_2+S1
R TiO_2+S1
R TiO_2
.4μ
.6
.8
1.0
1.2μ
10 X 10 TO THE CENTIMETER 46 1513

FIGURE 13

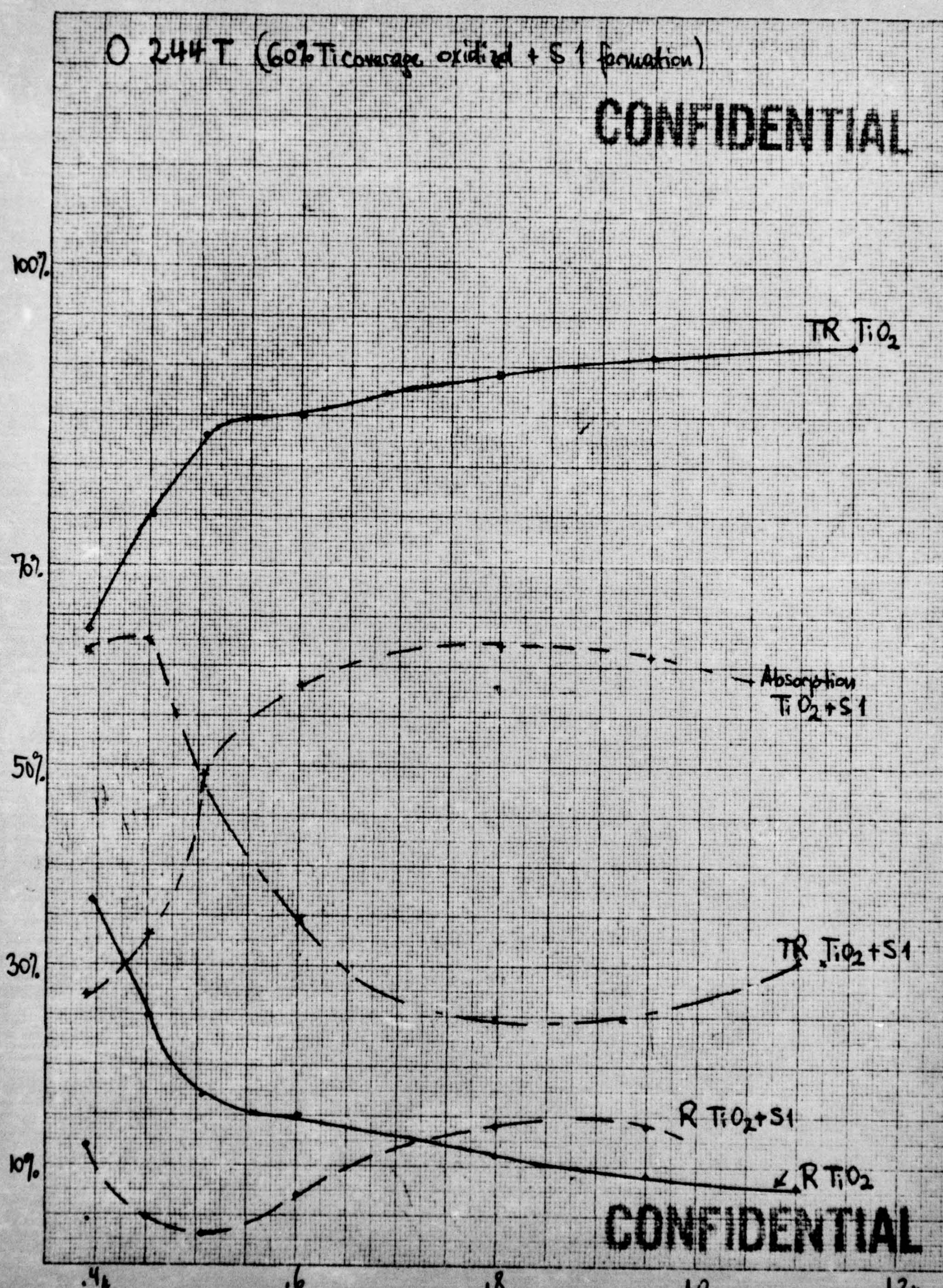
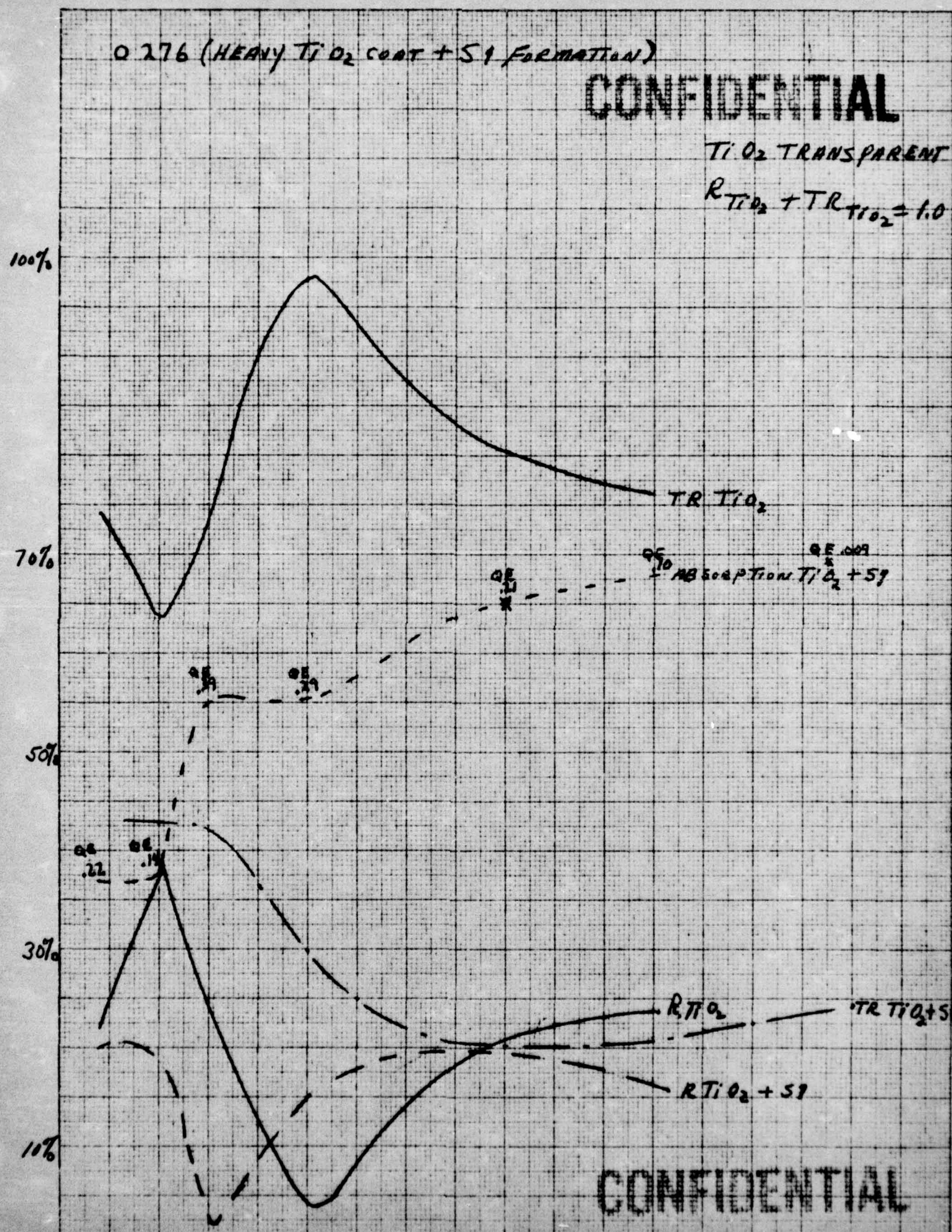

O 244 T (60% Ti coverage oxidized + S 1 formation)
CONFIDENTIAL
100%
75%
50%
30%
10%
TR TiO_2
Absorption TiO_2 + S 1
TR TiO_2 + S 1
R TiO_2 + S1
R TiO_2
CONFIDENTIAL
.4μ
.6
.8
1.0
1.2μ

FIGURE 14



O 276 (HEAVY TiO_2 COAT + SI FORMATION)
CONFIDENTIAL
TiO_2 TRANSPARENT
$R_{TiO_2} + TR_{TiO_2} = 1.0$
100%
70%
50%
30%
10%
$TR\ TiO_2$
ABSORPTION TiO_2 + SI
$R\ TiO_2$
$TR\ TiO_2$+SI
$R\ TiO_2$ + SI
.4
.6
.8
1.0
1.2 μ
CONFIDENTIAL

FIGURE 15

CONFIDENTIAL

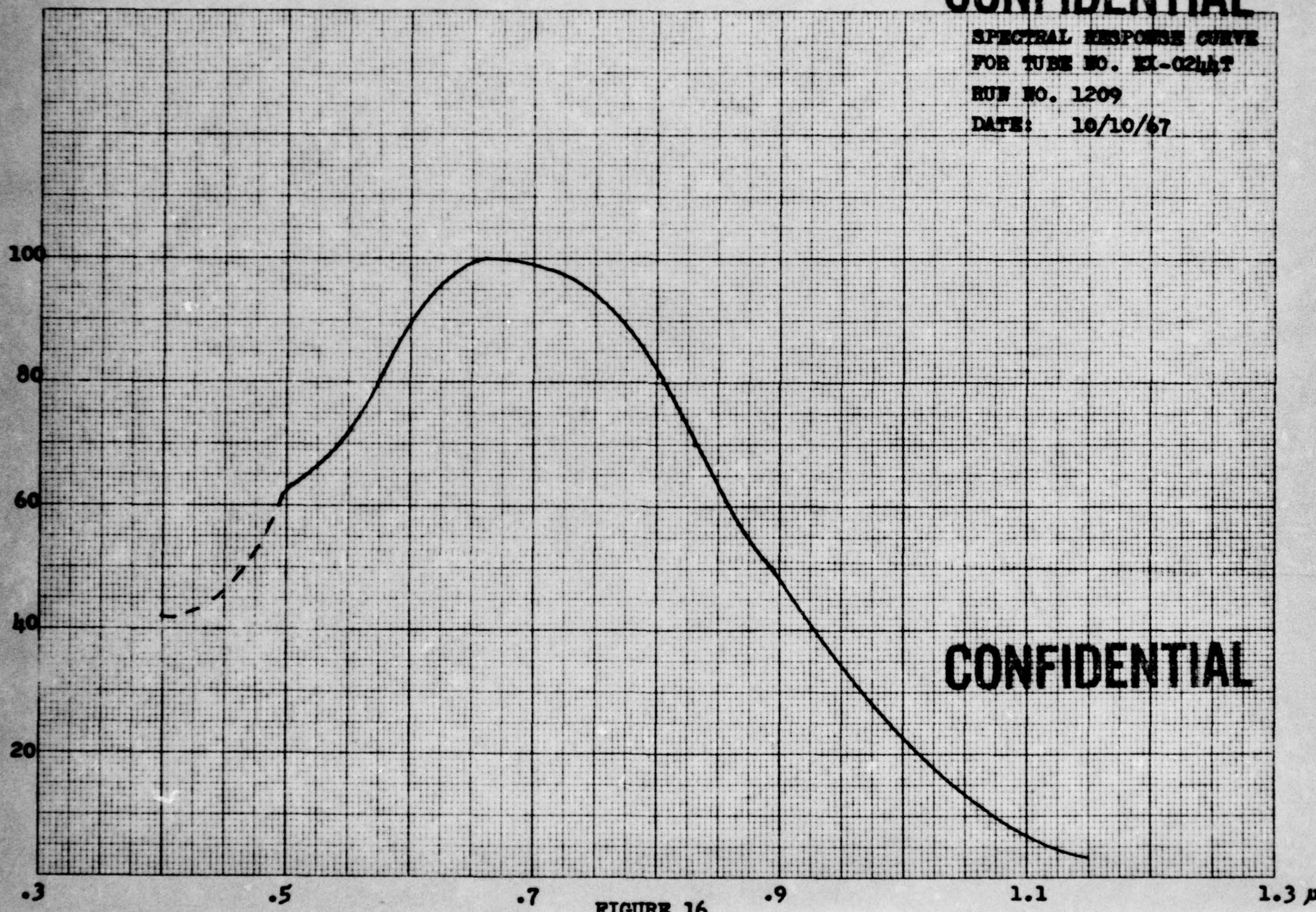


FIGURE 16

CONFIDENTIAL

CONFIDENTIAL

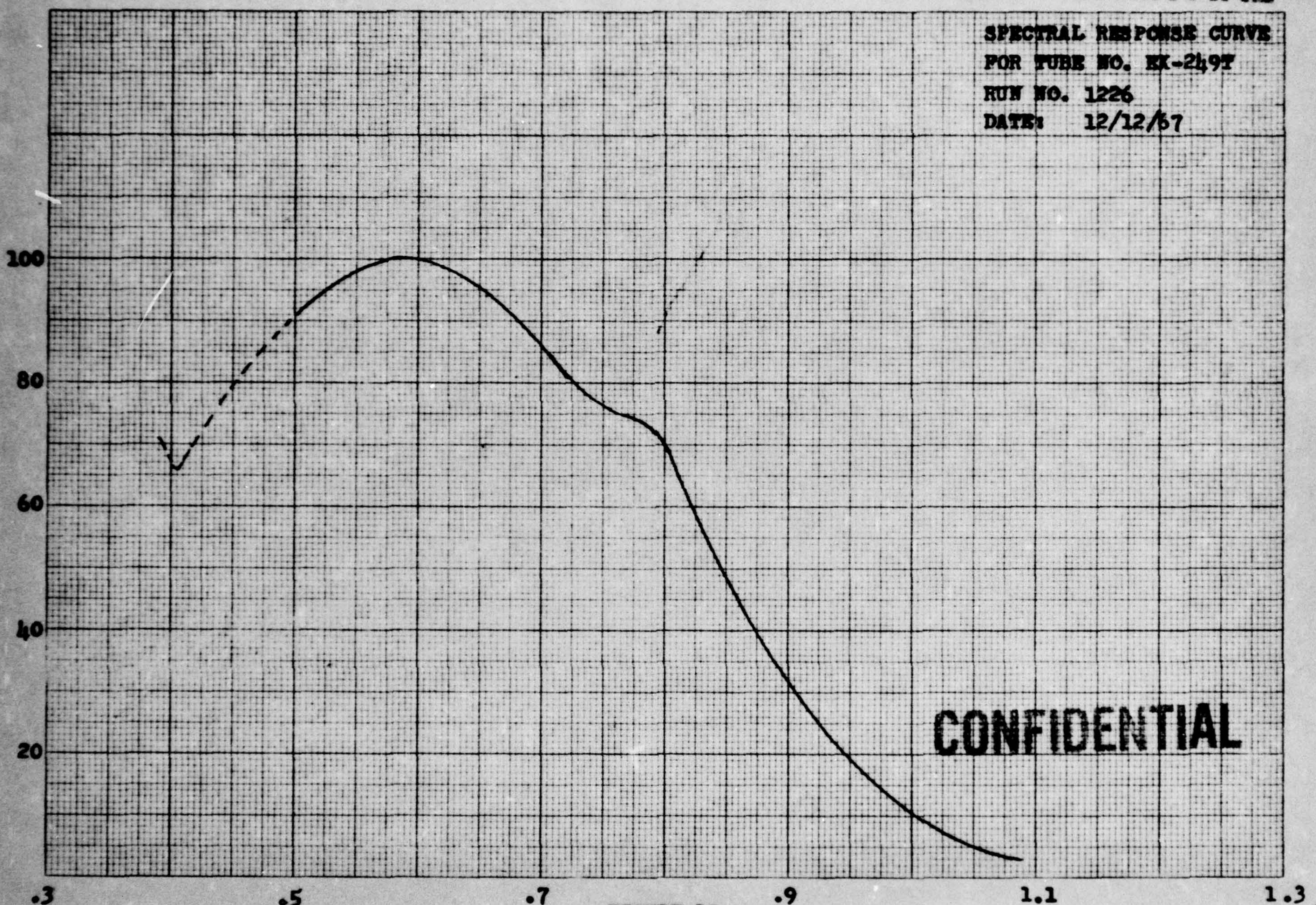


FIGURE 17

CONFIDENTIAL

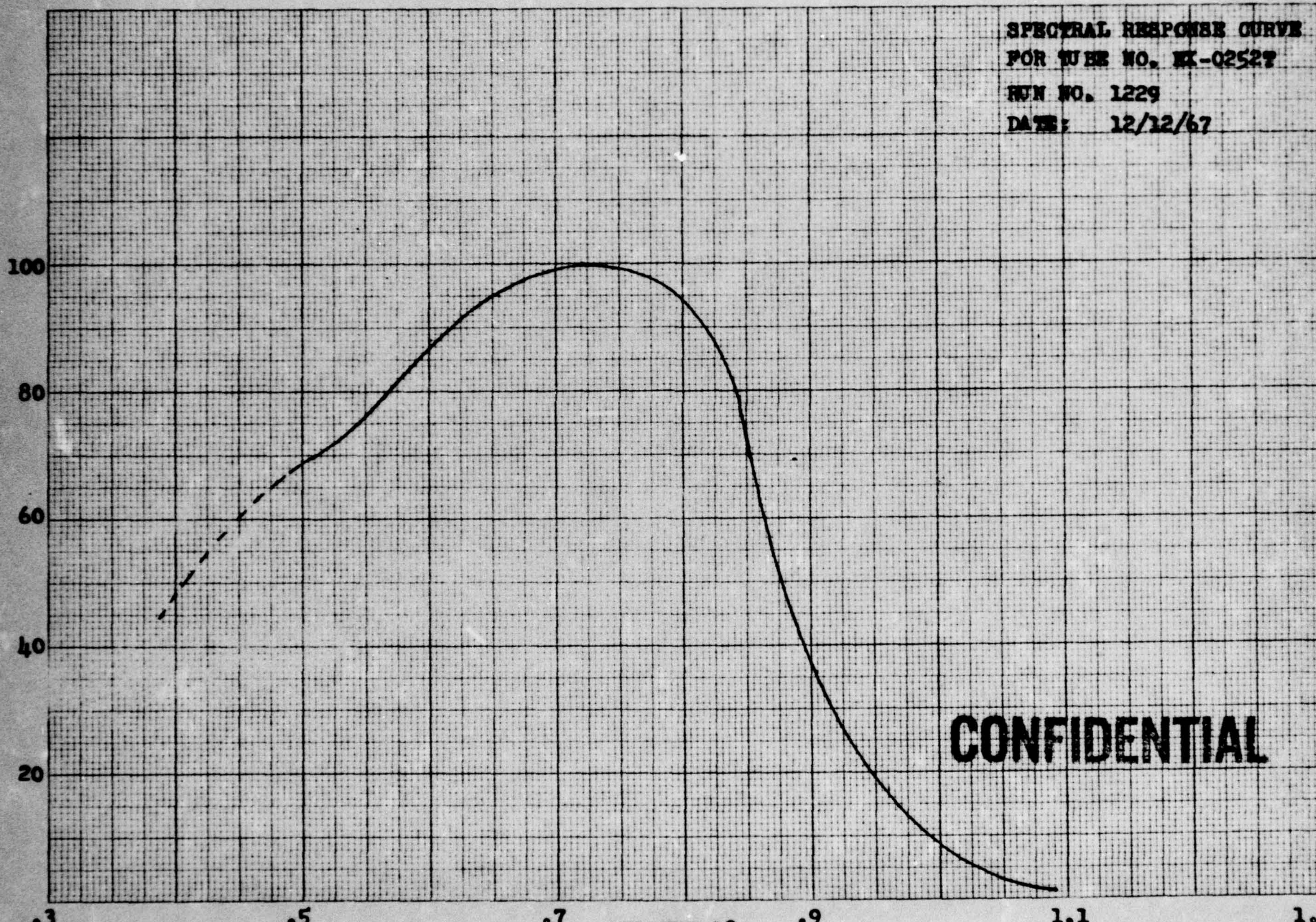

SPECTRAL RESPONSE CURVE
FOR TUBE NO. EX-02527
RUN NO. 1229
DATE: 12/12/67
100
80
60
40
20
.3
.5
.7
.9
1.1
1.3 µ

FIGURE 18

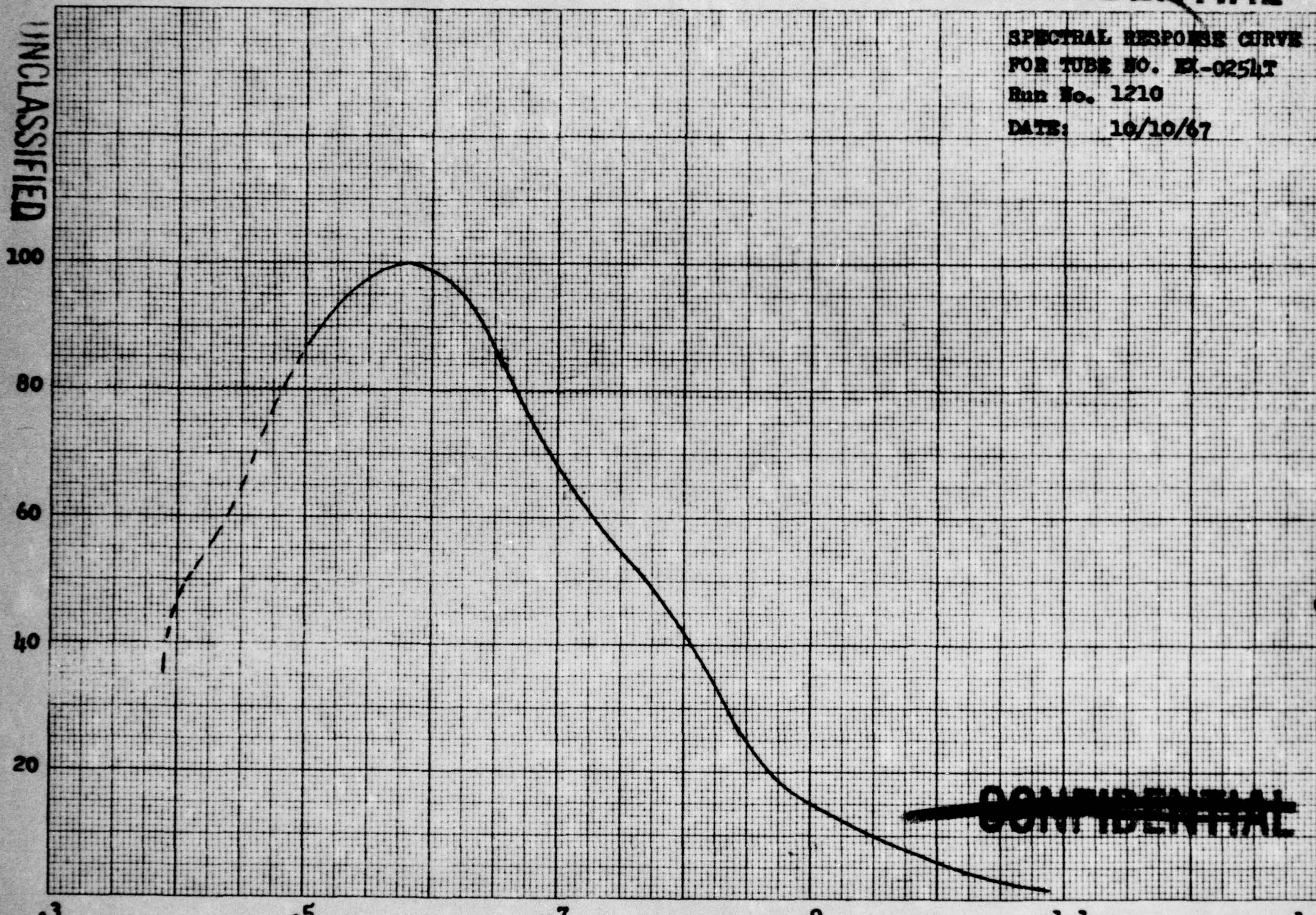
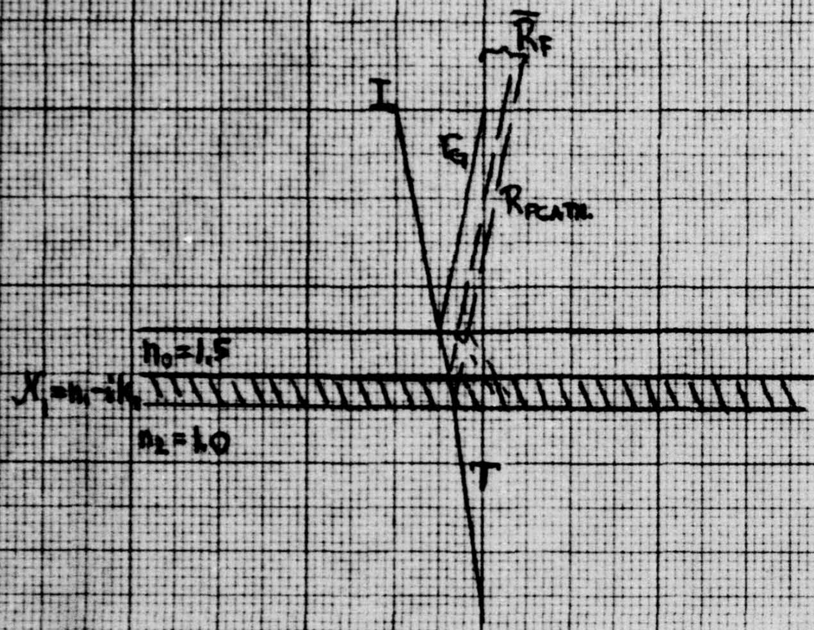
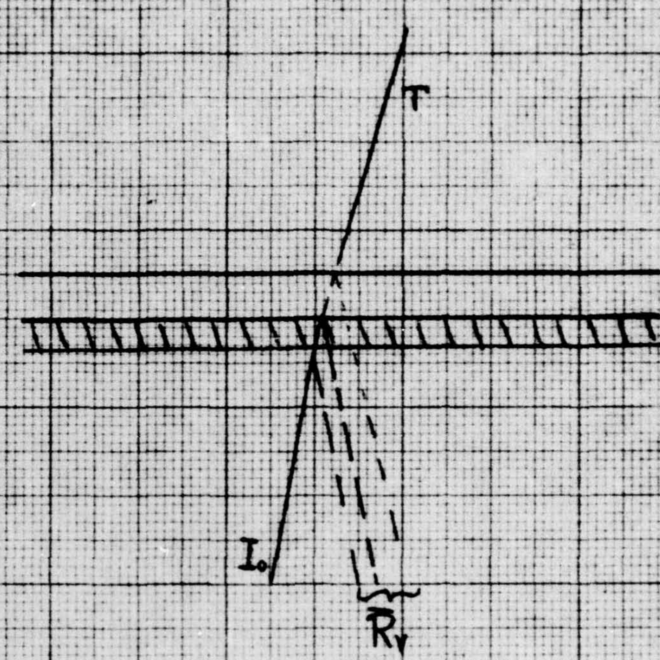

SPECTRAL RESPONSE CURVE
FOR TUBE NO. EX-0254T
Run No. 1210
DATE: 10/10/67
100
80
60
40
20
.3
.5
.7
.9
1.1
1.3 μ

FIGURE 19





$$\bar{R}_F = r_G + R_{PCATH.}$$

$$R_F = \frac{\bar{R}_F}{1-\epsilon}$$

$$(1-r_G)R_{FC}(1-r_G)+r_G = (1-\epsilon)R_F$$

$$T_F = \frac{T}{1-2r_G}$$

$$(1-r_G)T_{FC} = (1-2r_G)T_F$$

$$\bar{R}_V \simeq R_{PCATH.} + \dots$$

$$R_V = \frac{\bar{R}_V}{1-\epsilon}$$

$$(1-\epsilon)R_V = R_{VC}$$

FIGURE 20